Groundwater Cleanups: Optimization and New Solutions

September 20, 2001
Region 3 RCRA Corrective Action Meeting
Philadelphia, PA

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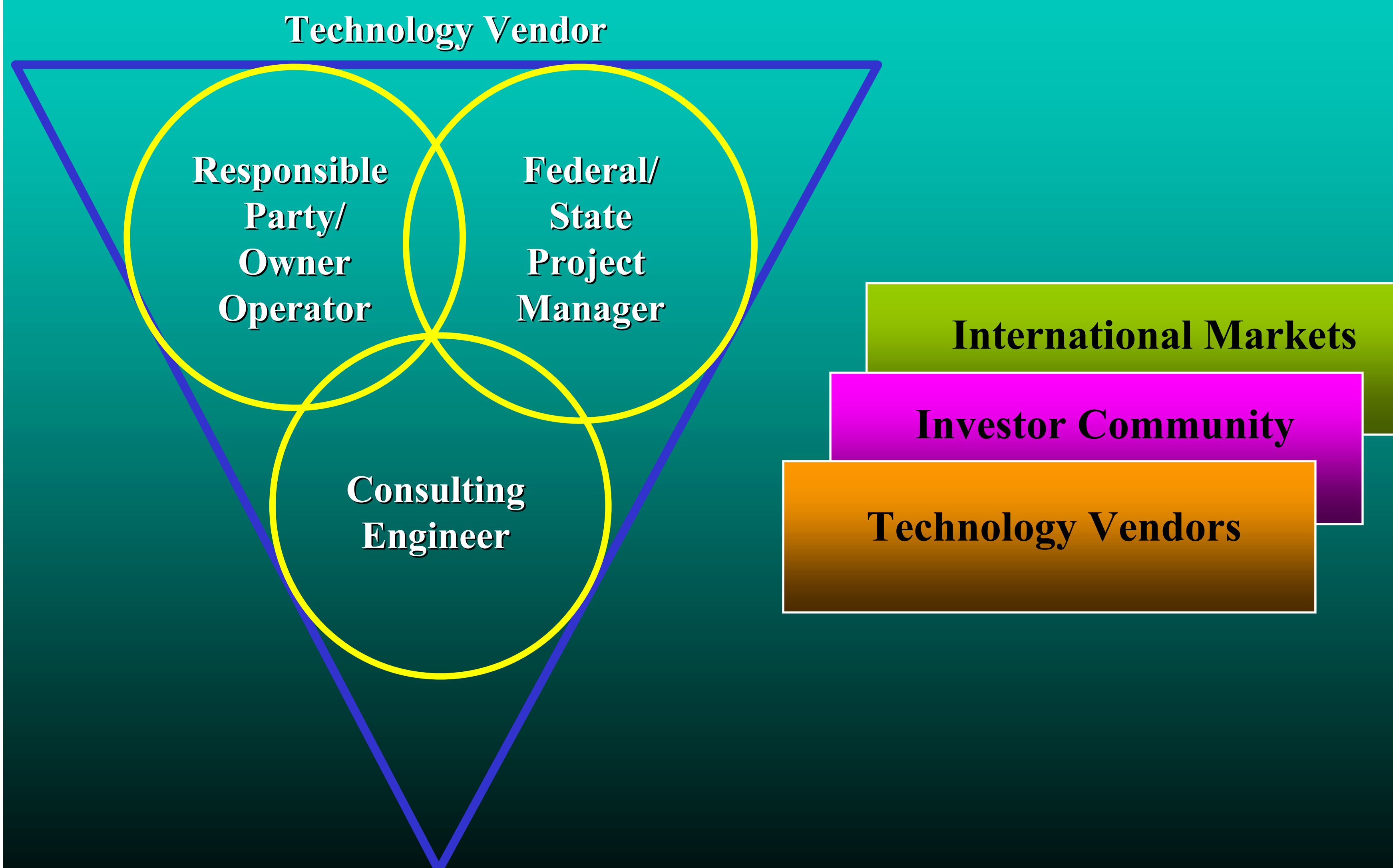
US Environmental Protection Agency

Technology Innovation Office

Clients for Information on Technology Innovations



TIO's Mission

- Advocates "smarter" technologies for the characterization and cleanup of contaminated sites
- Works with clients to identify and understand better, faster, and cheaper options
- Seeks to identify and reduce barriers to the use of innovative technologies

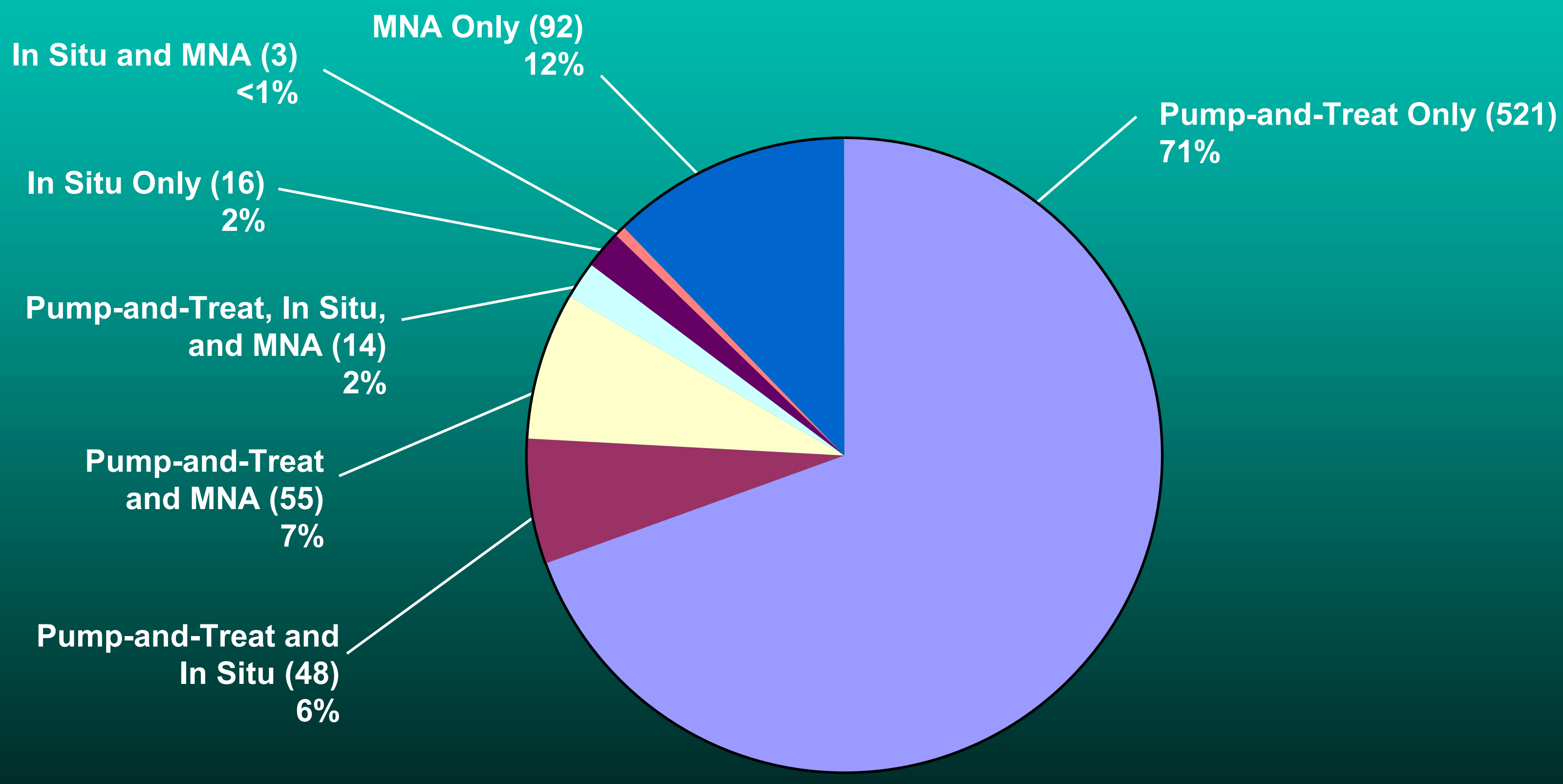
Technology Deployment and Cost

- EPA information
- Multi-agency data
- New reports

http://cluin.org/asr

Superfund Remedial Actions:
Groundwater Remedies (FY 1982 - FY 1999)

Total Sites With Pump-and-Treat, Monitored Natural Attenuation (MNA) and In Situ Groundwater Treatment Remedies = 749

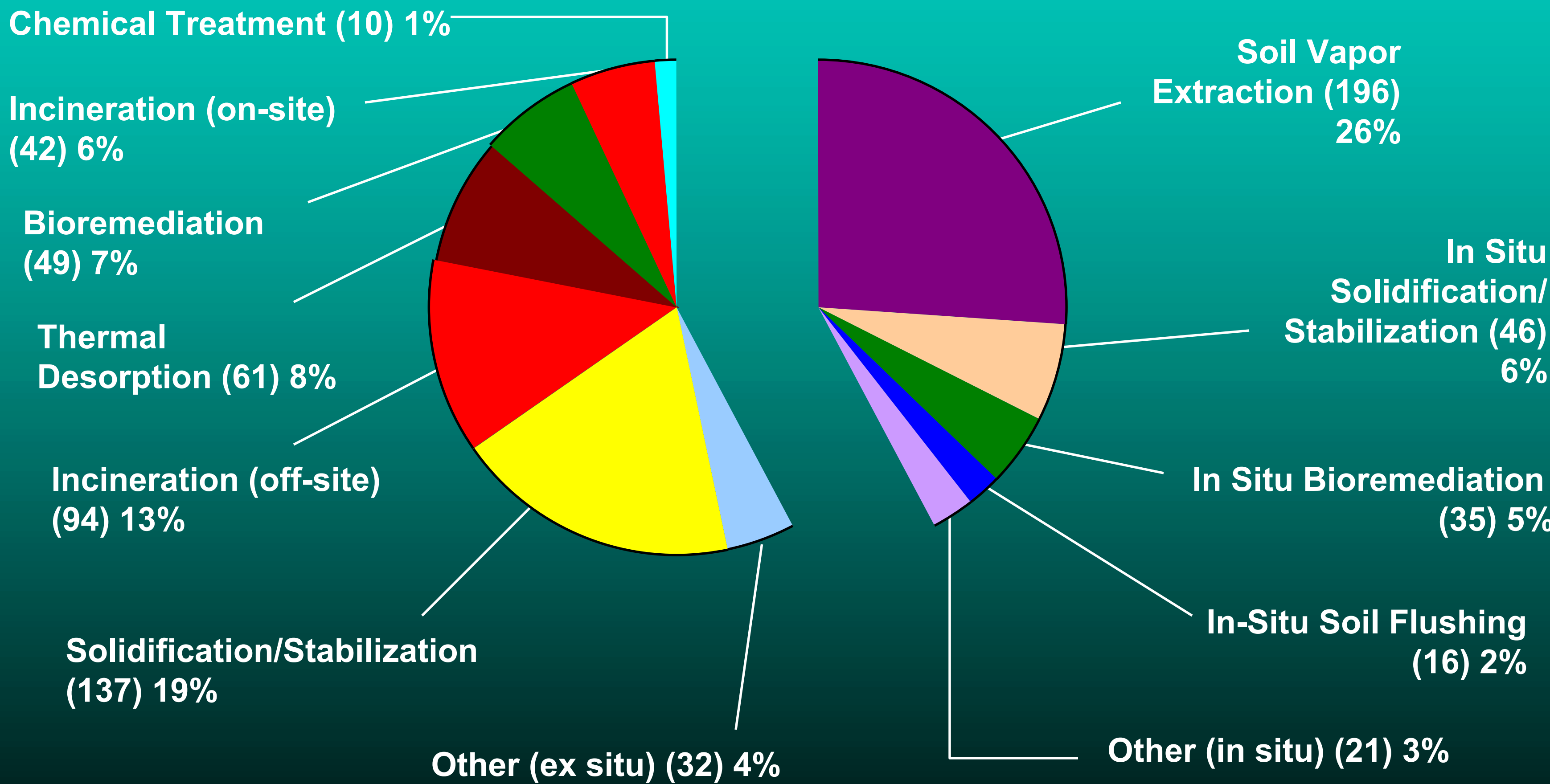


Source: *Treatment Technologies for Site Cleanup: Annual Status Report (Tenth Edition)*, U.S. EPA, EPA 542-R-01-004, February 2001

Superfund Remedial Actions:

Summary of Source Control Treatment Technologies (FY 1982 - FY 1999)

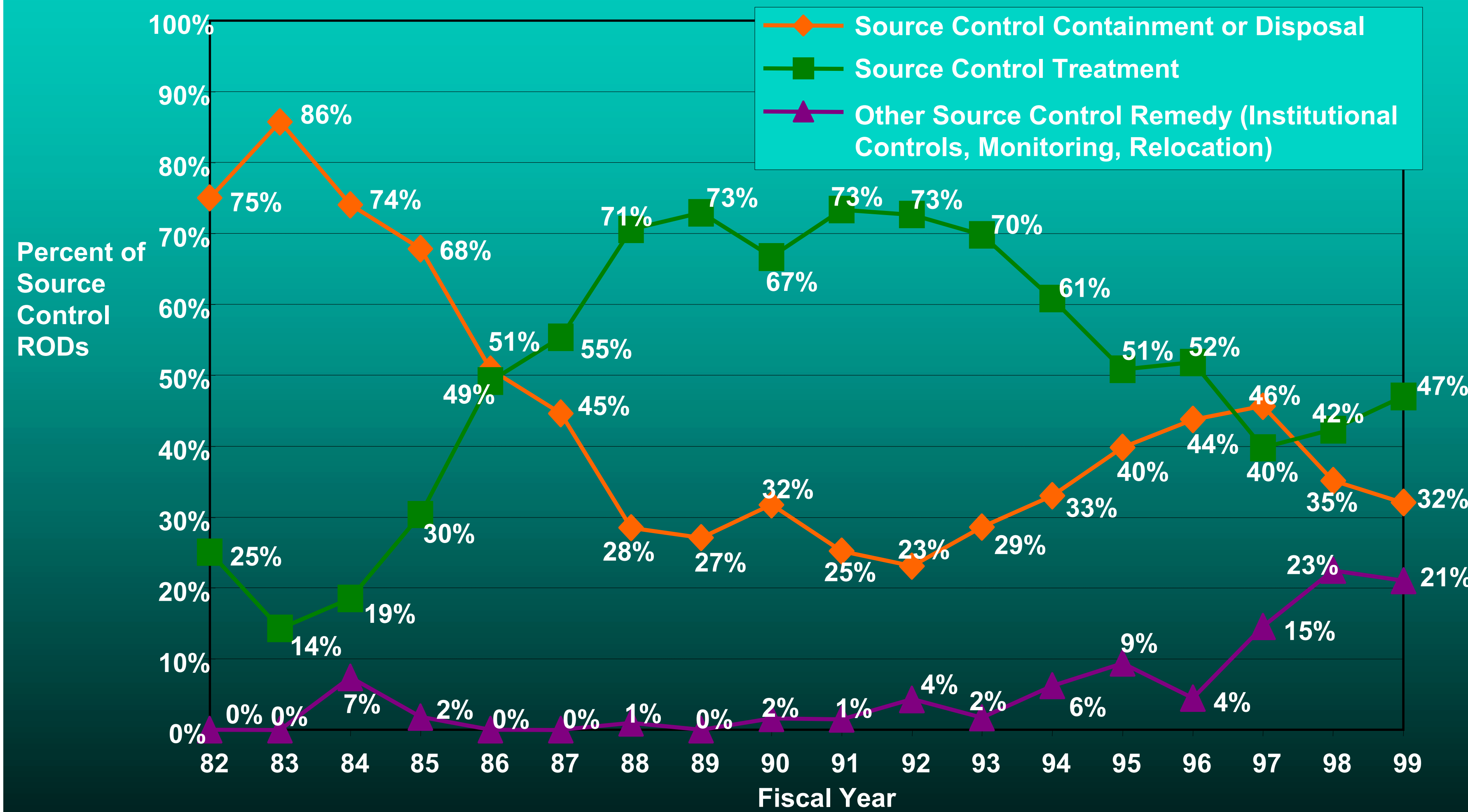
Ex Situ Technologies (425) 58% | **In Situ Technologies (314) 42%**



Source: *Treatment Technologies for Site Cleanup: Annual Status Report (Tenth Edition)*, U.S. EPA, EPA 542-R-01-004, February 2001

Superfund Remedial Actions:

Trends in Types of Source Control RODs (FY 1982 - FY 1999)



Source: *Treatment Technologies for Site Cleanup: Annual Status Report (Tenth Edition)*, U.S. EPA, EPA 542-R-01-004, February 2001

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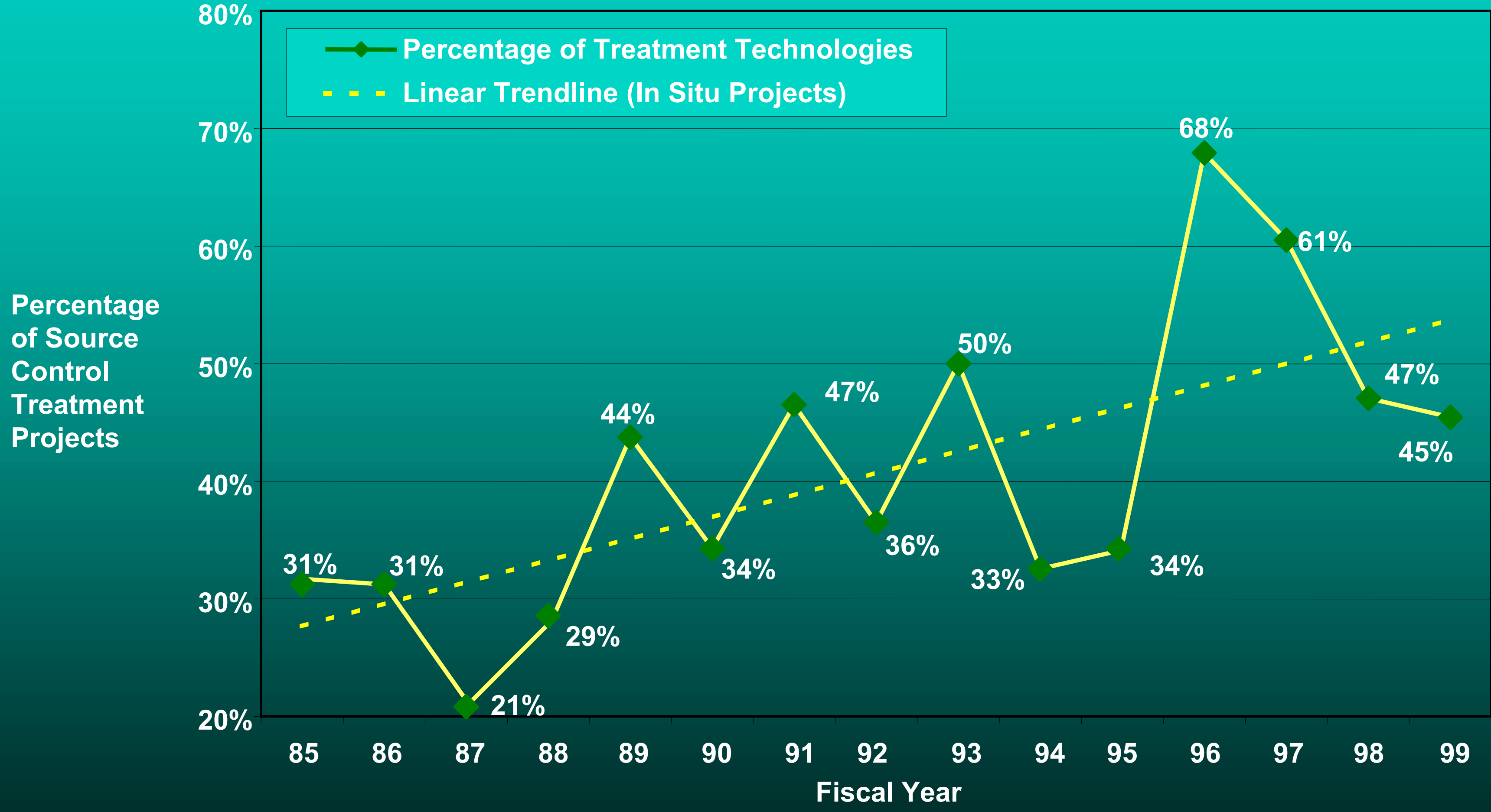
Superfund Remedial Actions:
In Situ Technologies for Source Control
(FY 1985 - FY 1999)



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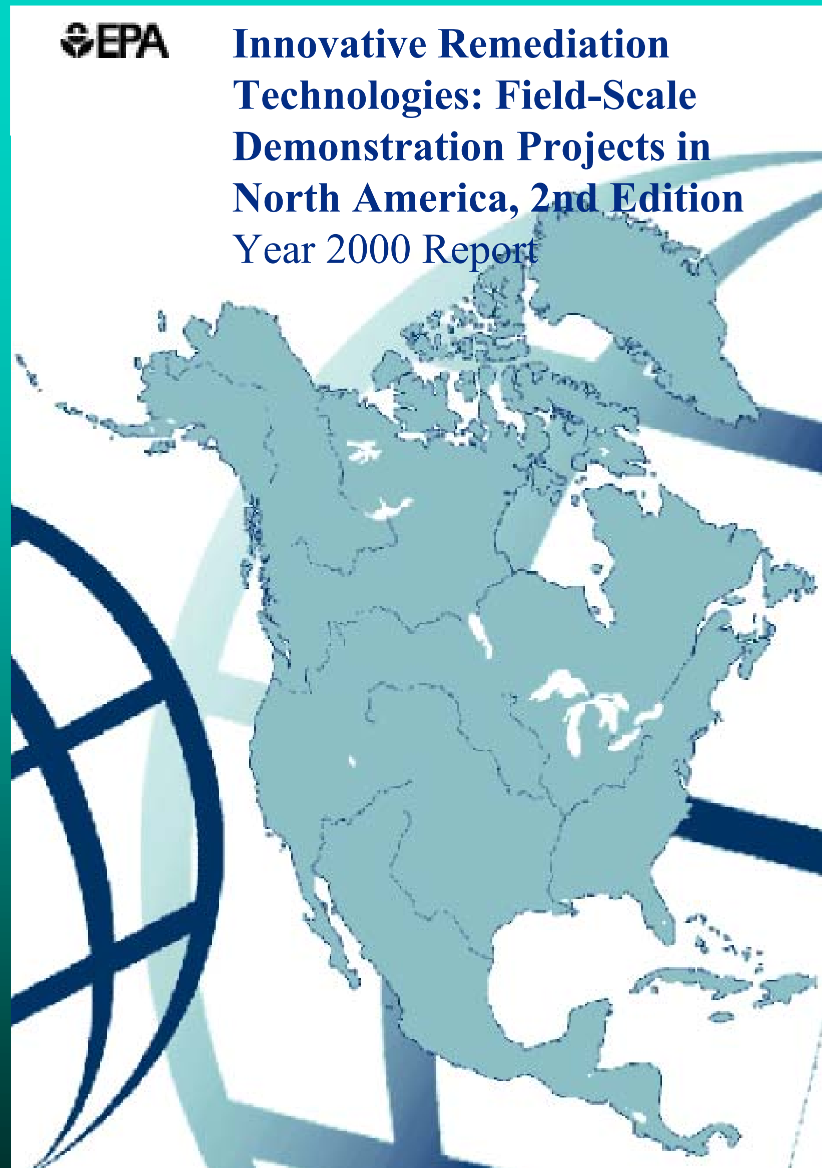


http://cluin.org/products/nairt/overview.htm

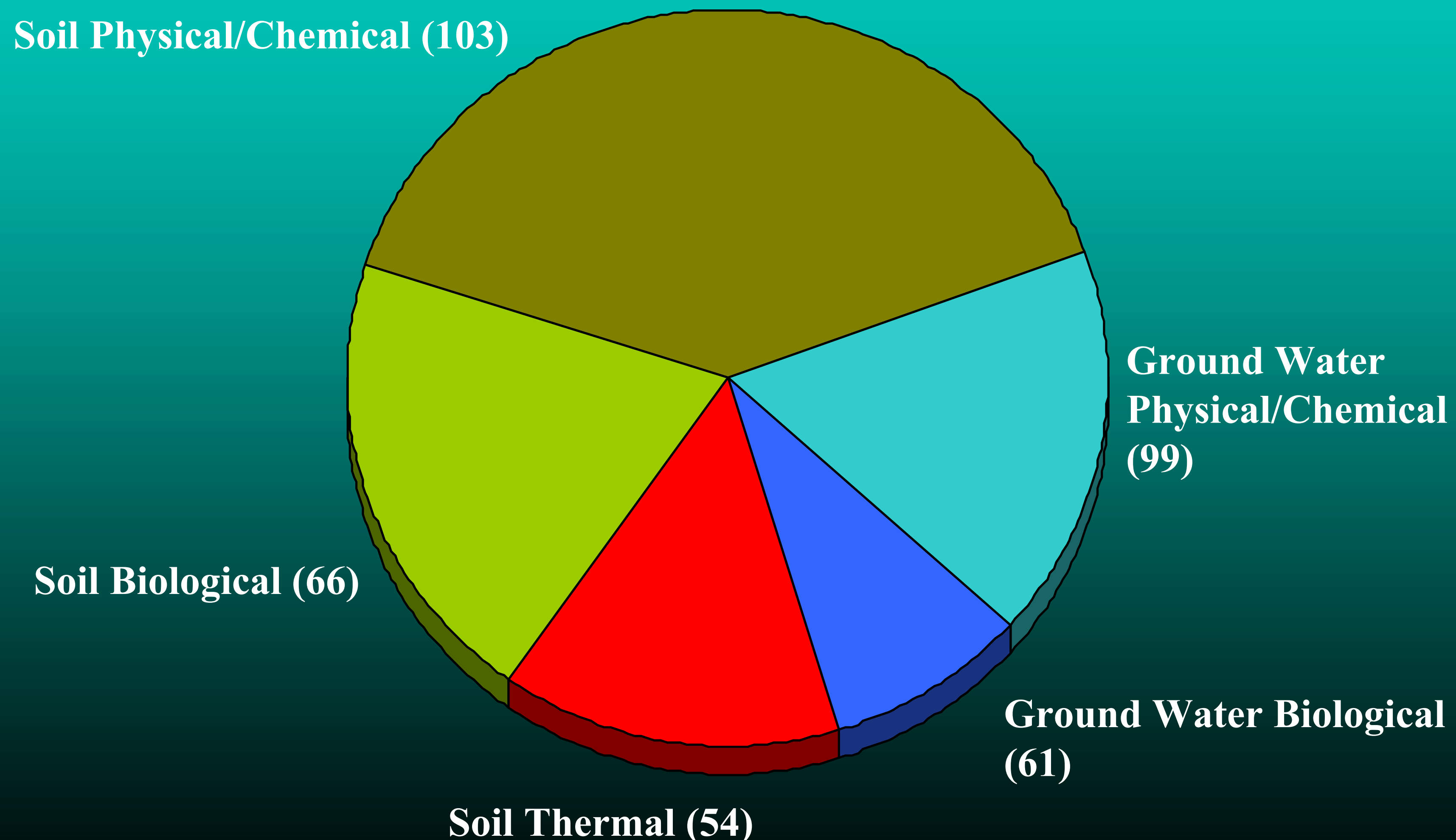
North American Innovative Technology Demonstration Projects Report

- Matrix summarizing 601 government-sponsored demonstrations (1985-present)
- Sponsoring government agencies (North America)
  - Canadian Government
  - U.S. Environmental Protection Agency
  - U.S. Military Services (Army, Navy, Air Force)
  - U.S. Department of Energy
  - California Environmental Protection Agency

http://clu-in.org/products/nairt/

North American Innovative Technology Demonstration Projects

In Situ Technologies 383 Projects



Federal Remediation Technologies Roundtable

FRTR
Remediation Case Studies

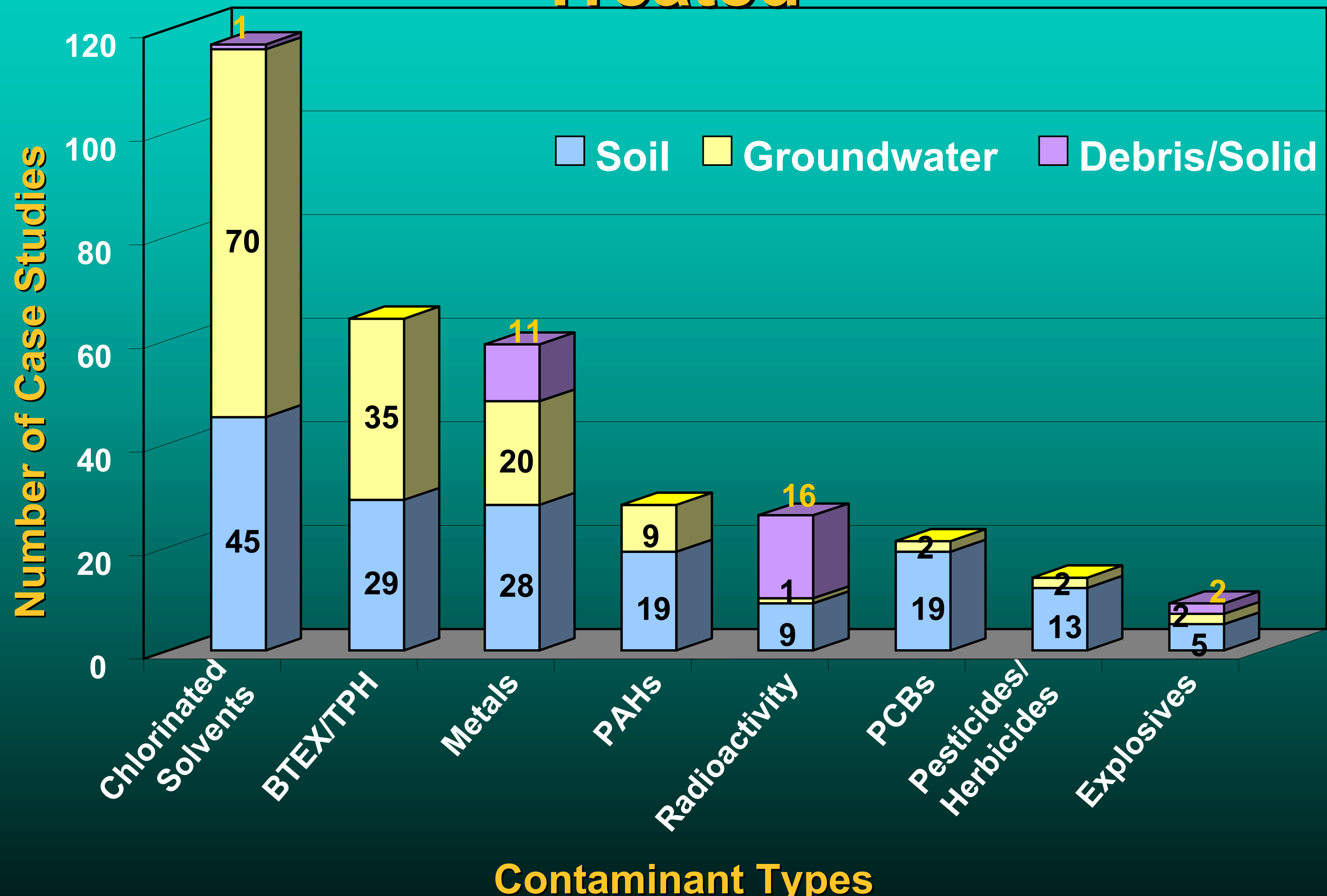
- Document cost/performance of clean-up technologies
- Includes full-scale cleanup and large-scale demonstrations
- 274 EPA, DoD, DoE cases
- Searchable by technology, contaminant, media (www.frtr.gov)
- Superfund, RCRA, State sites

FRTR Cost and Performance Guide

In Situ Groundwater Remediation Technologies with Recommended Reporting Elements

- Air Sparging
- Bioremediation
- Bioslurping
- Circulating wells (UVB)
- Cosolvents/surfactants
- Dual-phase extraction
- Dynamic underground stripping
- In situ oxidation (Fenton’s Reagent)
- Natural attenuation of nonchlorinated compounds
- Natural attenuation of nonchlorinated hydrocarbons
- Permeable Reactive Barriers
- Pump and Treat
- Phytoremediation
- Steam flushing
- Vertical barrier walls

FRTR Case Studies: Summary of Contaminants and Media Treated *



http://www.frtr.gov

* Some case studies address more than one type of media/contaminant

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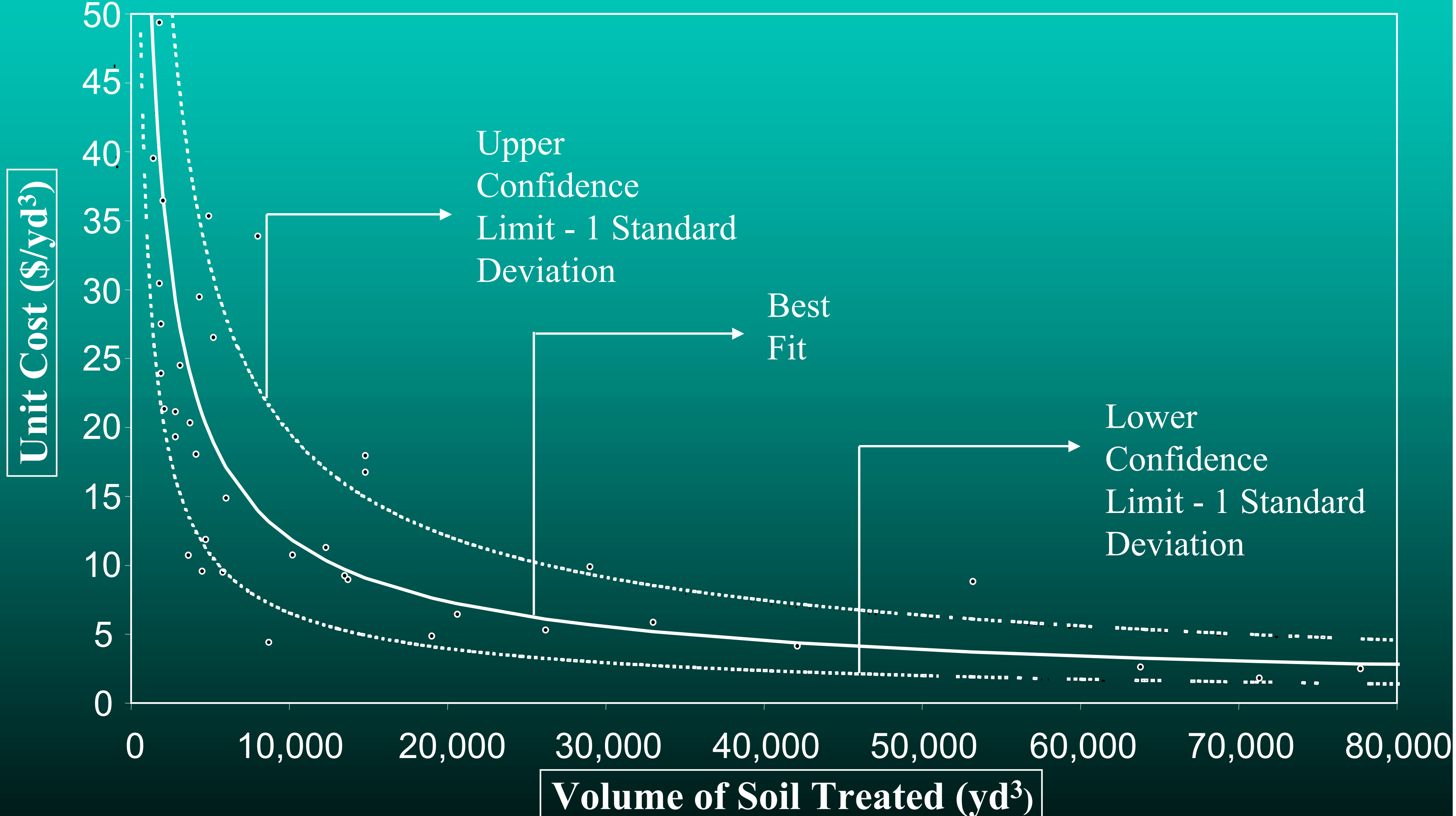
Remediation Technology Cost Compendium – Year 2000

- Historical cost data compilation for 6 cleanup technologies: bioremediation, thermal desorption, SVE, on-site incineration, pump-and-treat, and PRBs
- Focus on **unit cost** for quantity treated and contaminant mass removed
- "Fully defined" cost data
  - Based on actual applications from federal agency sources
  - Directly linked to technology application
- Cost curves developed
- Findings reconfirm factors driving remediation technology costs
- Available September 2001

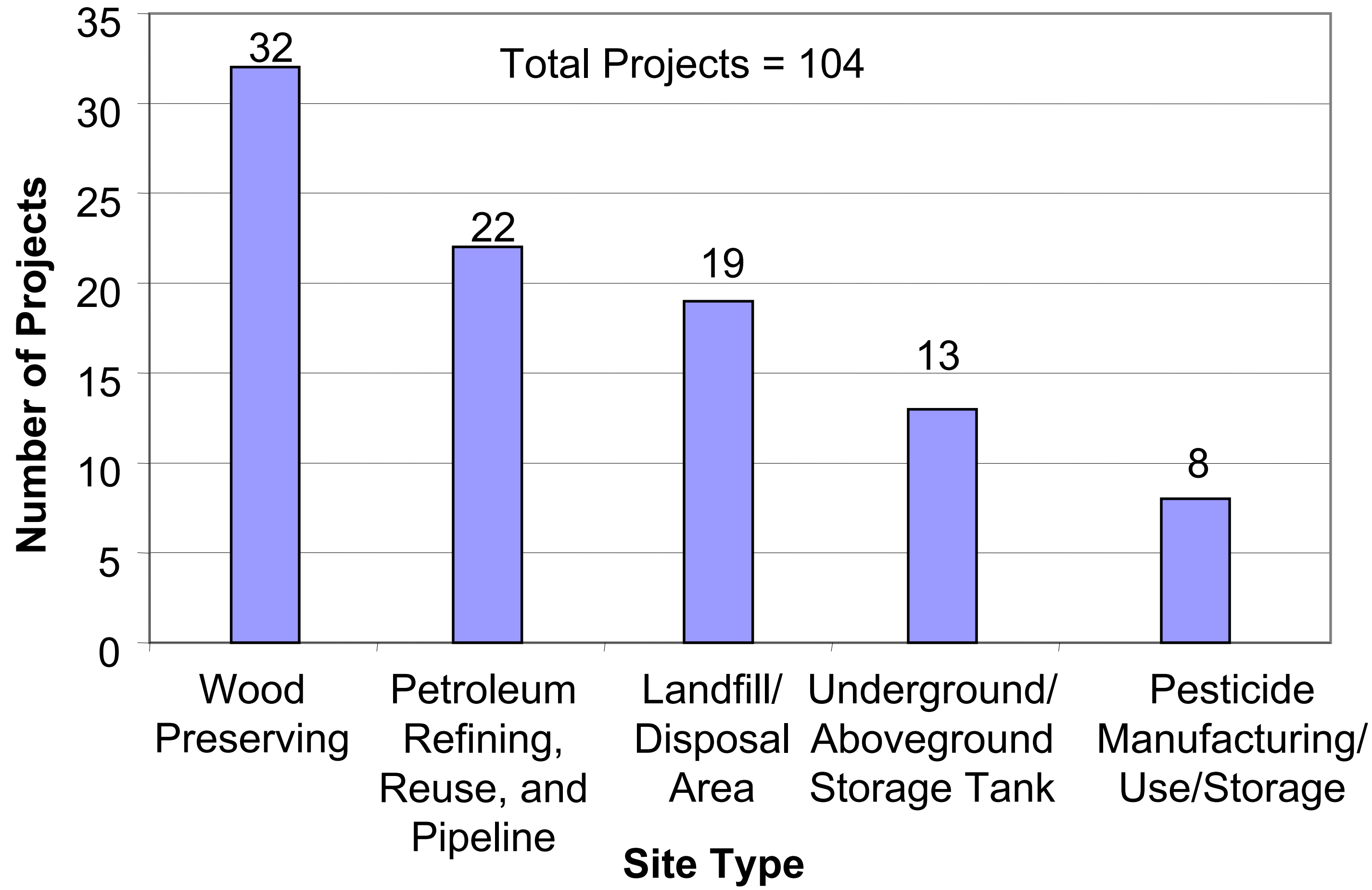
Bioventing Cost/Volume Curve
Remediation Technology Cost Compendium



Use of Bioremediation at Superfund Sites

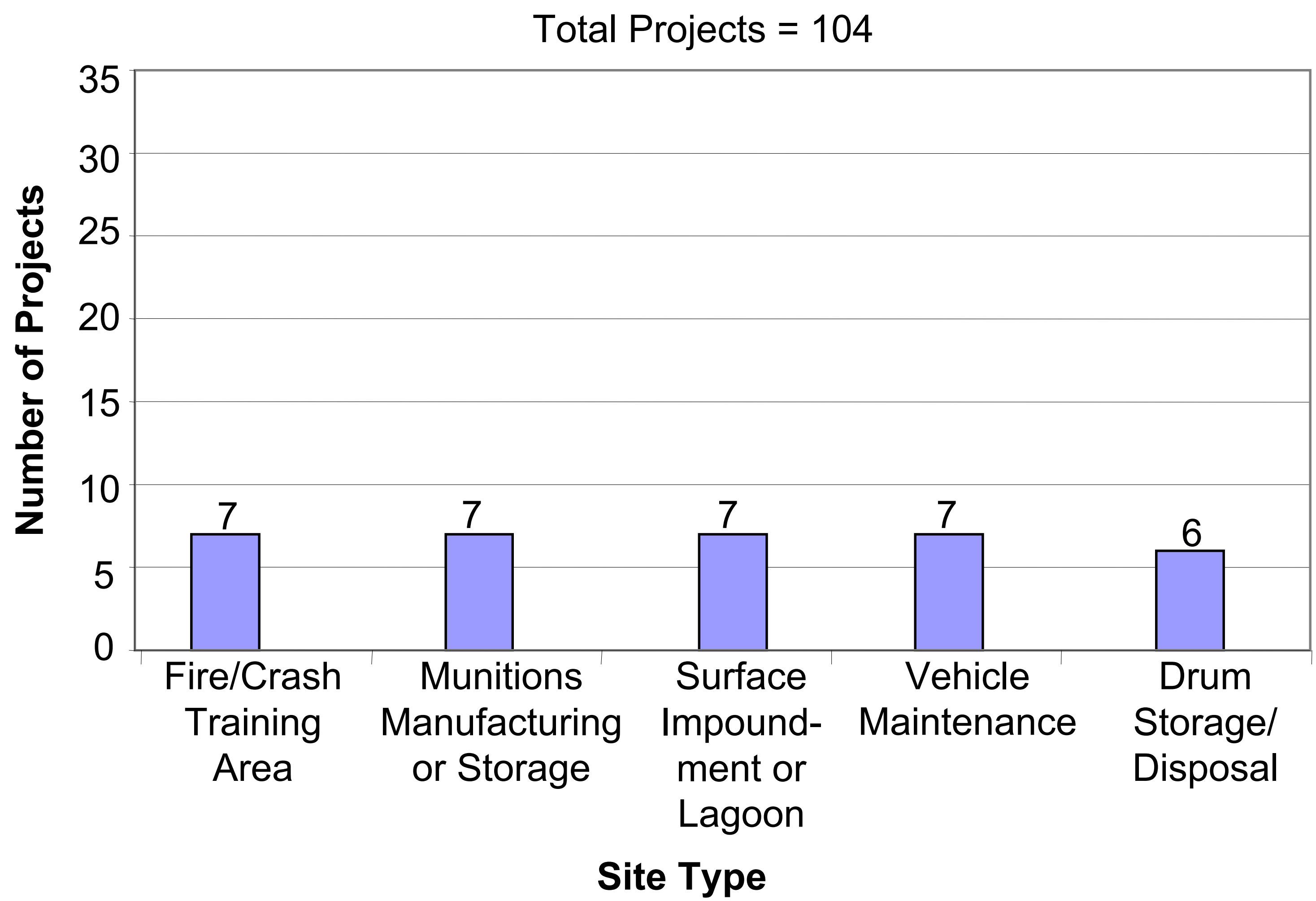
- Recent report on status-48 pages
- Describes site-specific applications of ex situ and in situ bioremediation at 104 Superfund sites
- Summarizes contaminants and media treated
- Provides available cost and performance data
- Analyzes trends over time
- http://cluin.org/techpubs.htm

Superfund Site Types Most Commonly Treated by Bioremediation (FY 1982 – FY 1999)[1] Part 1 of 2



[1] Some sites are described by more than one site type.

Superfund Site Types Most Commonly Treated by Bioremediation (FY 1982 – FY 1999)[1]
Part 2 of 2



[1] Some sites are described by more than one site type.

Contaminant Groups Treated by Bioremediation Technologies at Superfund Sites (FY 1982 – FY 1999)

In Situ Treatment

Techno-logy	Total No. of Projects	PAHs	Other Non-Chlori-nated SVOCs	BTEX	Other Non-Chlori-nated VOCs	Pesti-cides And Herbi-cides	Other Chlori-nated SVOCs	Chlori-nated VOCs	Explo-sives/ Propel-lants
Source Control									
Bioventing	24	●	●	●	●	●	●	●	
Slurry Phase	2	●			●	●	●	●	
Other	9	●	●	●		●		●	
Groundwater									
Biosparging	3	●	●	●	●			●	
Injection/ Recirculation	17	●	●	●	●	●		●	

ETV

EPA's Environmental Technology Verification Program

http://www.epa.gov/etv

ETV Site Characterization and Monitoring Technologies Pilot

Categories	Technologies Verified	Report Status
Cone penetrometer/laser-induced fluorescence	2	Completed
Field-portable XRF (SITE)	7	Completed
Field portable GC/MS	2	Completed
Soil/soil gas sampling (SITE)	6	Completed
Well-head monitoring of VOCs	5	Completed
PCB analysis	9	Completed
Decision-support software	6	Completed
Ground water sampling	6	Completed
Explosives test kits	4	Completed
TPH test kits (SITE)	5	In Peer review
Sediments sampling (SITE)	2	Completed
Lead-in-dust detection	8	New Project

EPA REACH IT System

- Free information service, searchable on-line
- Vendor information on 371 treatment and 160 characterization technologies
- Detailed site information on 900 EPA Superfund remediation projects
- Flexible search options including by technology, contaminant, media, and sites
- Will be updated continuously by EPA and vendors (Fall 2001)

http://www.epareachit.org

Looking Down the Road

- “Smarter” site monitoring will save money before, during, and after cleanup
- Post construction activities gaining in importance
- Economics and feasibility of groundwater DNAPL source control in transition

Monitoring: Saving Throughout the Process

"Let's get through characterization and on to cleanup"

The Triad Approach

Systematic Planning

Dynamic Workplanning

On-Site Measurement Technologies

Characteristics of the "Triad"

- Fully maximizing capabilities of **field analytical instruments** and rapid sampling tools
- **Systematic planning**
  - Meeting site or project-specific goals vs. prescriptive methods "checklists"
  - Relying on thorough advance planning/up-front understanding of the site
  - Global view of project, ultimate goals
- **Dynamic** or adaptive decision making
- Bringing together the right **team**
- Changing **perception**
  - Requirements for accurate, protective, and defensible decisions
  - Time, money, and quality

Wenatchee Tree Fruit Facility: Remediate Pesticide “Disposal” Plot

- Initial EPA estimate: excavate, transport and incinerate 708 tons of soil = $1M (not including closure testing)
- USACE plan: Pesticide immunoassay kits guided sampling, removal, and disposal decisions in 1 mobilization using dynamic work plan
- Outcome: 334 tons landfilled; 56 tons incinerated
  - Total Cost of Project at Closeout (including COE oversight fees of $100K) = $589K
  - Project Lifetime = 6 months

Cost Comparison (per USACE)

	Traditional	DWP
1. Review Existing Data	$7,150	$11,000
2. Design Site Characterization	$0	$17,640
3. Implement Site Characterization	$0	$84,134
4. Review Char. data	$0	$10,000
5. Design Remedy	$16,500	$26,460
6. Implement Remedy (- Disposal)	$168,094	$271,116
7. Waste Disposal	$910,000	$153,570
8. Closure report	$20,305	$20,305
TOTAL	**$1,122,049**	**$594,225**

This traditional cost estimate assumes no characterization, only removal and incineration of the entire plot volume

New Emphasis on Improved O&M and "Close Out"

"We're done when construction is complete"

Future Obligations are Significant

- Optimization of pump and treat
- Improving efficiencies of groundwater monitoring
- Rethinking source term vs. plume management

Superfund Reform Initiative: Pump and Treat Optimization

- July 7, 2000 — Superfund Program included pump and treat (P&T) optimization in Superfund Reform Initiative
- Collaborative effort between TIO/OERR/Regions to showcase Remedial System Evaluation (RSE) process at Fund-lead P&T systems
- Project Goals
  - Perform RSEs at 20 Fund-lead P&T systems (out of 88)
  - Increase awareness of need and benefit of optimization
  - Provide assistance to RPMs in evaluating results and implementing recommendations
  - Incorporate optimization into overall clean-up process

Overview of Results from 16 RSEs

- Cost reductions identified at 13 of 16 sites
- Improvements in remedy effectiveness identified at 12 out of 16 sites
- Significant cost savings opportunities found at 10 out of 16 sites: 15-73% reduction in annual O&M costs)

Summary of Estimated Cost Savings

	Potential Changes in Annual and Capital Costs			
	RSE of P&T System 1		RSE of P&T System 2	
Region	Annual cost savings	Capital investments	Annual cost savings	Capital investments
1	($149K/yr)	$117K	($2.1M/yr)	$133K
2	($570K/yr)	$827K	Draft not finalized	
3	($40K)	$175K	$42K	$120K
4	($35K/yr)	$99K	($62K/yr)	$225K
5	($113K/yr)	$40K	($203K/yr)	$233K
6	($25K/yr)	$105K	($58K/yr)	$81K
7	($22K/yr)	$59K		

Total Potential Cost Savings = $3.3M/yr for 12 sites

Estimated Capital Investments = $2.2M for 12 sites (one-time cost)

Common Themes Regarding Cost Reduction

- Over design of aboveground treatment systems
  - Many aboveground treatment systems designed to treat max. concentrations and flow rates found during the RI
  - Because actual operational parameters lower than anticipated, many can be downsized to more efficient units

- Costly on-site analytical work and excessive process monitoring
  - Several sites had on-site labs and high frequency of process monitoring
  - RSE team found on-site labs not cost effective and high-frequency process monitoring unnecessary - led to increased labor costs

Common Themes Regarding Cost Reduction, cont.

- Alternate discharge options
  - Several sites had very low POTW discharge limits that should be revisited to determine if higher limits possible
  - Operators and site personnel not aware that POTW limits uncommonly low
- Potential use of alternative technologies
  - Permeable reactive barriers, in situ chemical oxidation, and other innovative in situ treatment technologies recommended at some sites
- Some O&M contracts were inefficient

Common Themes Regarding Remedy Effectiveness

- Remedy effectiveness needs to be more closely monitored
  - Most sites did not adequately evaluate whether P&T system captures the plume (1 out of 16 sites had adequately evaluated capture zone)
  - Most sites did not carefully evaluate O&M reports
  - Most O&M reports did not provide adequate interpretation of data, for example:
    - Mass removal over time
    - LTM data against clean-up goals
    - Influent and effluent data against design specifications
- Site close out needs to be better defined
  - Many sites do not have agreed upon exit strategies
  - Systems continue to operate without being required by the ROD

Key Message from Reviews to Date

GROUNDWATER REMEDIATION SYSTEMS REQUIRE ACTIVE MANAGEMENT

- Revisit system objectives
- Evaluate subsurface performance
- Evaluate aboveground performance
- Evaluate potential cost reductions
- Develop exit strategy
- Evaluate contract efficiency

Next Steps

- Next FY:
  - Complete 10 additional RSEs
  - Complete fact sheet on “Important Components to Effective Pump and Treat System Operation, Maintenance, and Monitoring”
  - Complete guide to evaluating groundwater capture zones

Improving Efficiencies of GW Monitoring Systems

- EPA demonstration project to evaluate effectiveness of geostatistical approaches for GW monitoring optimization
- Approach: 4 sites with existing GW monitoring plans being evaluated with geostatistical approaches
- Benefit: Geostatistics can provide more quantitative approach to determine if spatial (in space) and/or temporal (in time) redundancies or deficiencies exist
- Schedule: 4 case studies and white paper on geostatistics to be completed by Winter 2001

Ranking Criteria for Difficulty in Remediating Ground Water

National Research Council, 1997

Hydrogeology	Mobile Dissolved (Degrades/Volatilizes)	Mobile Dissolved	Strongly Sorbed, Dissolved	Strongly Sorbed, Dissolved (Degrades/Volatilizes)	Separate Phase LNAPL	Separate Phase DNAPL
Homogeneous, Single Layer	1	1-2	2	2-3	2-3	3
Homogeneous, Multiple Layers	1	1-2	2	2-3	2-3	3
Heterogenous, Single Layer	2	2	3	3	3	4
Heterogenous, Multiple Layers	2	2	3	3	3	4
Fractured Bedrock	3	3	3	3	4	4

least difficult = 1 / most difficult = 4

Rethinking Source Term vs. Plume Management

- Potential source term control solutions
  - Chemical oxidation
  - Surfactant-cosolvent flushing
  - Steam/heat
- Outstanding issues
  - Science
  - Policy
  - Other

Dynamic Underground (Steam) Stripping

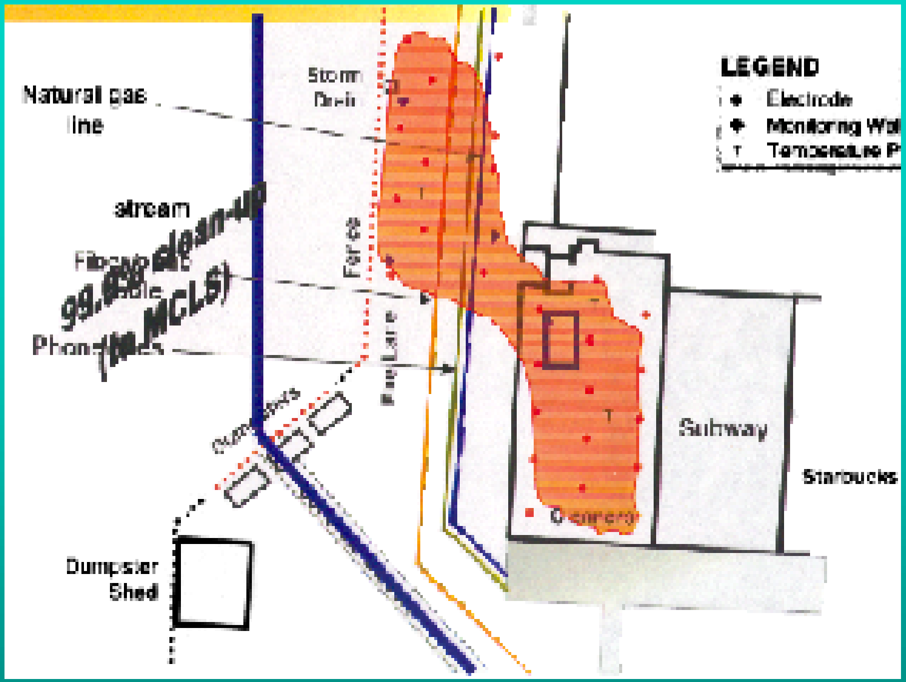
- Visalia Pole Yard NPL Site in S. California
- Former wood (pole) treatment facility
- Creosote, PCP
- Pump and treat started in 1976, 10lbs/week
- Began steam stripping (dynamic underground stripping-DUS) 3 years ago
- 100,000 lbs removed in first 6 weeks
- >1,300,000 lbs removed to date
- Goal to meet MCLs
- More work needed to reduce costs

Visalia Steam Remediation Project

- Total project cost: $21.5 M 1996 through 2000
- Unit cost per cubic yard of soil treated
  - Actual cost $57
  - With lessons learned $38
  - Solvent and fuels $25
- Comparative cost per gallon of creosote removed
  - P&T $26,000
  - DUS $ 130
- Estimated time to remove 1.3 M pounds of creosote
  - P&T 3250 years
  - DUS 3 years

Small Site: Soil Treatment Technologies Six-Phase Heating

- Heats soils to remove organics in soil *in situ* (in place)
- Costs: \$30-60/CY, \$20-45/ton (electric 10-15% of costs or \$3-9/ton)
- Ideal for "tight" soils – problematic condition for standard soil vapor extraction (SVE)
- Example: former dry cleaner in active retail center
  - Solvent (PCE) contamination: 2,000 ppb in soil, 3,600 ppb in groundwater
  - Guaranteed cleanup to drinking water standards (MCLs) in 4 months (500 ppb in soil, 5 ppb in groundwater)



Six-Phase Heating

Seattle Dry Cleaning Site

- Fast-track property transfer
- PCE in soil and groundwater
- Cleanup within 4 months
- To MCLs (5 ppb in water)
- Continued property use

In Situ Thermal Clean-up Projects
http://clu-in.org/products/thermal

Organization	# of Projects
Navy	9
Air Force	5
Army	4
DOE	5
Private	37

Technologies Included:

- Conductive Heating
- ERH- Electrical Resistance Heating
- Hot Air Injection
- RF- Radio Frequency Heating
- SEE- Steam Enhanced Extraction

“Take Home” Messages

- Technology cost and performance information IS available
- Saving money on the “grey panthers” is likely
- “Smarter” measurement and monitoring throughout the site “life cycle”
- New approaches to groundwater DNAPL’s are “with us”

CLU-IN World Wide Web Site
http://clu-in.org

CLU-IN

EPA United States Environmental Protection Agency

Technology Innovation Office

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Hazardous Waste

Clean-Up Information

Publications & Software

Remediation

Site Characterization

Partnerships & Consortia

International Updates

Vendor Support

TechDirect

Y2K

- Site Remediation Technologies
- Site Characterization Technologies
- Technology Partnerships, Roundtables, and Consortia
- Updates on International Clean-Up Activities
- Vendor Support
- Publications for Downloading
- Free E-mail Updates via TechDirect
- Regulatory Information and Technology Policy
- Links to Other Internet and Online Resources

TechDirect

Highlights

- Broadcasts periodic e-mail messages to list of over 11,000 subscribers
- Highlights events of interest to site remediation and site assessment professionals
- Describes new products and provides instructions on how to obtain them

Top 10 Websites For Hazardous Waste Management

1. http://clu-in.org (or http://www.epa.gov/tio)
2. http://www.epareachit.org
3. http://www.frtr.gov
4. http://www.gwrtac.org
5. http://www.rtdf.org
6. http://www.epa.gov/ORD/SITE
7. http://em-50.em.doe.gov
8. http://www.itrcweb.org/
9. http://www.serdp.org/research/research.html
10. http://www.epa.gov/etv/